

Providing Real-Time Biofeedback for Amputee Gait Retraining Using LabVIEW

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THE CHALLENGE

Developing a real-time biofeedback training system to augment sensory feedback provided to lower-limb amputees.

Products:

LabVIEW, MathScript RT Module

Limb Amputation

Amputation is considered to be an invasive clinical intervention, yet an often necessary measure against diseases such as bone cancer, diabetes, and vascular diseases, or in cases of trauma and intractable pain. Approximately 5,000 new referrals are received every year in the UK for limb amputations. Amputees are fitted with prosthetic limbs soon after surgery and undergo a period of intense physiotherapy as part of their rehabilitation.

For example, leg amputation not only results in reduced mobility but also a loss of the sensory neural pathways that give people a sense of limb positioning and identity. The neural pathways required to regulate walking are impaired in lower-limb amputees and it can often be difficult to learn to effectively use artificial limbs. Patients commonly experience neurological problems such as phantom limb pain for years after surgery and can develop poor postural and walking habits that can lead to lower back pain and reduced quality of life. Therefore, it is important to improve the sensory integration between the prosthesis and the wearer.

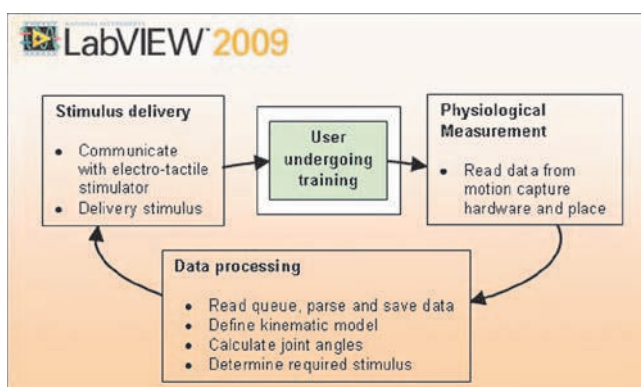


Figure 1. Biofeedback Training System Overview

Biofeedback

This project uses a technique called biofeedback to artificially provide that sense of limb position. Biofeedback is a training technique that uses instrumentation to measure a physiological process and present that information back to the patient undergoing training. We believe that embedding a biofeedback system into the prosthesis

THE SOLUTION

Using a high-speed optical motion capture system to provide coordinates of retro-reflective markers placed on the body, a client written using NI LabVIEW software to read the data stream and construct a linked-segment model, and parallel MathScript Nodes to calculate the relative joint angles of the legs.

can, in part, fill the sensory gap left by limb loss. A biofeedback system includes four major components: a physiological process, a measurement system, data processing, and a means of stimulus presentation. The ease of user interface (UI) design and the improved processing performance of LabVIEW made it a clear choice to sit at the centre of the system integration.

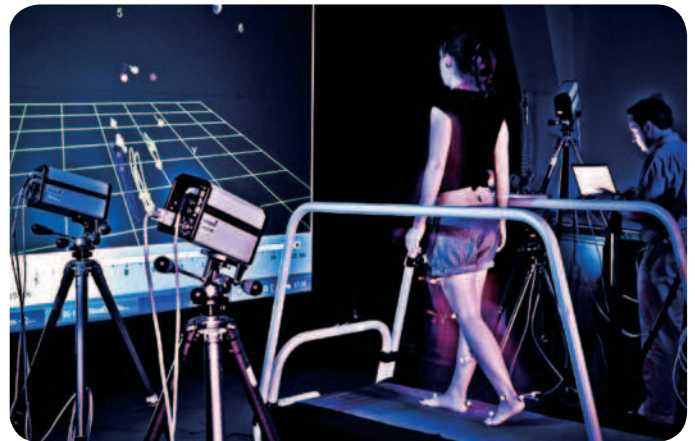


Figure 2. Optical Motion Capture System

System Design

Physiological Measurement

We use an optical motion capture system (ProReflex from Qualisys in Sweden) to capture the coordinates of retro-reflective markers placed on the body and output frames of data through a TCP/IP connection at 100 Hz. The system operates on a standard desktop PC running a Windows OS, which creates a great demand for efficient data processing. We use the producer-consumer architecture within LabVIEW to ensure no data packets are lost and sufficient time is provided for real-time calculations. Using LabVIEW, we developed a multithreaded application that enabled each loop to operate on separate processor cores with a higher priority than Windows.

Data Processing

To determine relative joint angles between body segments, a closed-chain kinematic model is defined using the marker coordinates and anthropometric measurements of the body. Joint angles are then determined from the elements of a generalised transformation matrix. The real-time constraint requires that matrix

calculations be performed within many parallel MathScript Nodes using the greater LabVIEW MathScript RT Module processing efficiency. All data is saved to file using the NI Technical Data Management Streaming (TDMS) file format.

Stimulus Delivery

Feedback is conveyed to the patient through electrical stimulation of the skin surface. We developed a novel electro-tactile display that delivers a sensation through an array of electrodes worn inside the artificial limb. Each electrode stimulates the sensory receptors on the skin surface in a safe and painless manner and information can be presented through stimulus intensity, or spatially when the electrodes are used together. By comparing the actual movement of a patient's limb segment with the desired movement pattern set by clinical staff, an error function is produced that selects which electrode becomes active.

For example, Figure 3 shows a cross section of the thigh at an instant in time with an electrode ring. The blue circle represents the desired hip joint angles, whilst the green circle represents the patient's actual hip position. The active electrode is selected according to the angle of the vector connecting the two crosshairs. Stimulus intensity is proportional to the vector magnitude. As the patient walks the stimulus moves around the thigh, providing a sensation of a boundary. The clinical team can set the boundary according to the patient's goals as they progress through rehabilitation.

Working with NI

We took advantage of the constant evolution of the LabVIEW real-time platform in incorporating new features and advanced performance every year with the new release; this was made easy with ongoing support from NI engineers in the UK and Texas. Detailed advice was provided on the system architecture and the efficient use of MathScript code.

The system is currently undergoing performance profiling and safety testing and clinical trials will commence in the near future. We believe that greater benefits can be gained when the system is used ubiquitously outside the clinic using body-worn technology. Thus, we designed the software modules with the potential for later migration into an inertia-based, body-worn measurement system.

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We designed the device to be used by physiotherapists within a busy rehabilitation centre, so it was important to ensure the expert user has full control of system operation and is provided with necessary clinical data. This was second nature with the LabVIEW UI design.

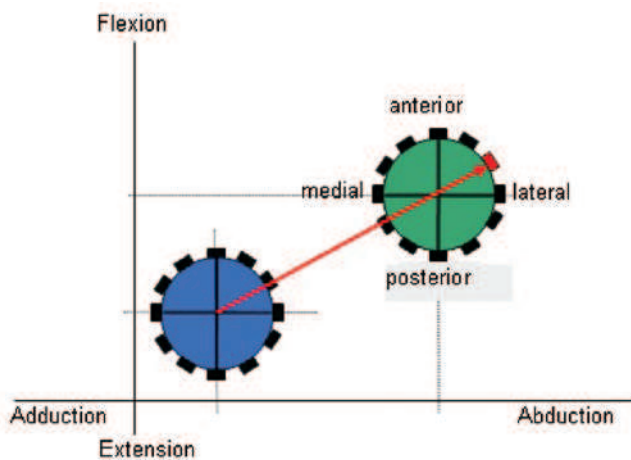


Figure 3. Scheme for Electrode Selection and Stimulus Intensity